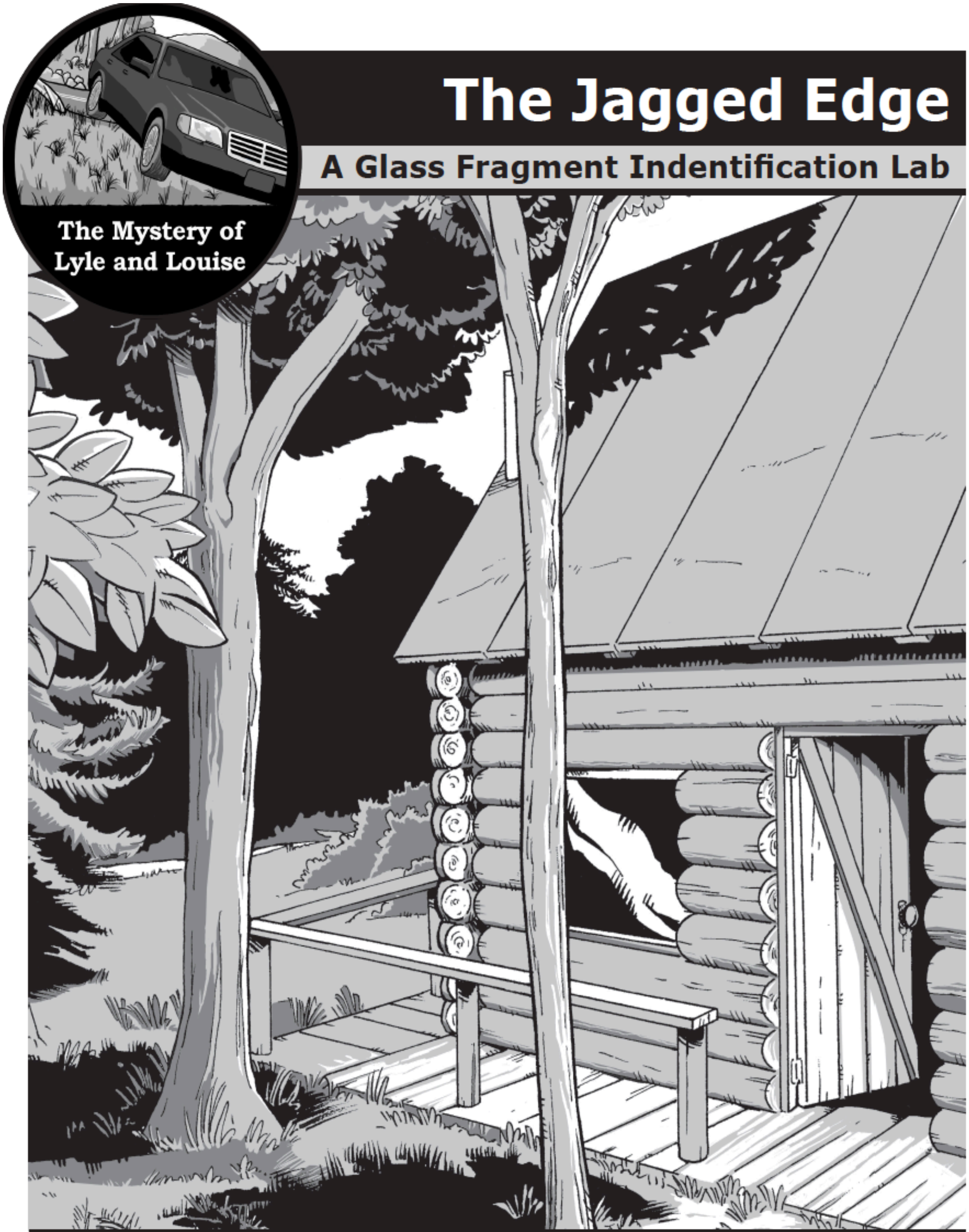
The Jagged Edge

A Glass Fragment Indentification Lab



Rev. 7/1/2012

Glass Fragment Identification

FORENSIC chemistry is a major subdivision of the forensic science discipline. In forensic chemistry a significant amount of analysis involves trace evidence. Trace evidence is evidence created when two objects come in contact with one another, and, generally, involves the transfer of matter between these two objects as a result of that contact. Examples of trace evidence collected from crime scenes frequently include items such as hairs, fibers, and paint chips. Trace evidence is of great importance in forensic science because, as a result of direct contact, trace evidence can link a suspect to a victim, a victim to a crime scene, and/or a crime scene to a suspect.

One such item of trace evidence that may be generated at a crime scene is broken shards of glass. Glass shards are frequently generated at a crime scene by the breaking of windows or, in the instance of automobiles, collisions. While broken glass may result in additional information at a crime scene, such as blood and DNA evidence in the event of cuts, in the absence of this evidence the broken glass itself may connect a suspect or victim to a crime scene.

If broken glass is to be matched to a suspected source, the first step in glass analysis is frequently an attempted physical match. If acceptable physical characteristics exist the glass pieces may be matched to the glass source physically by putting the glass back together, much like the assembling of a puzzle. Examples of such physical characteristics may include lettering, numbering, coloring, shape, and edge striations, or parallel lines or grooves on the edge of the broken pieces of glass. For court purposes, if a physical match can be made between glasses, generally, analysis then ceases.

In the absence of a physical identification of glass shards, additional analysis is often required. One method for the further analysis of glass is determination of the refractive index (RI) of the glass shards. Once the RI of the evidentiary (questioned) glass is determined it can then be compared to the glass from the crime scene. For instance, if broken glass fragments are collected from the clothing of a burglary suspect, the RI of those fragments can be determined. The RI of this glass can then be compared to the RI of the glass from a broken window of the burglarized home. Should those two glass samples exhibit the same RI, a potential connection could be made between the suspect and the crime scene. Should the two glass samples exhibit differing RIs, the suspect could potentially be excluded. Additionally, if evidentiary glass is from an unknown source, the RI of the glass may indicate what type of glass the unknown is.

Glass Type	Refractive Index Range
Vehicle Headlight	1.47-1.49
Television	1.49-1.51
Window	1.51-1.52
Bottle	1.51-1.52
Ophthalmic Lens	1.52-1.53

The RI of a substance is a measure of the speed at which light travels through that medium. This is expressed as a ratio of the speed of light in a vacuum to the speed of light traveling through the medium being analyzed. As a result of light traveling through mediums of differing RIs, the light becomes refracted, or bent. This means that because of the change in speed of the wave of light, the direction of that wave also changes.

The RI of a substance may be calculated from the amount of refraction exhibited by the light as it passes through varying mediums based upon the change in the angles of the wave. The angle at which the light enters the medium is known as the angle of incidence. The angle which the wave is bent is called the angle of refraction. This calculation is performed according to the following formula:

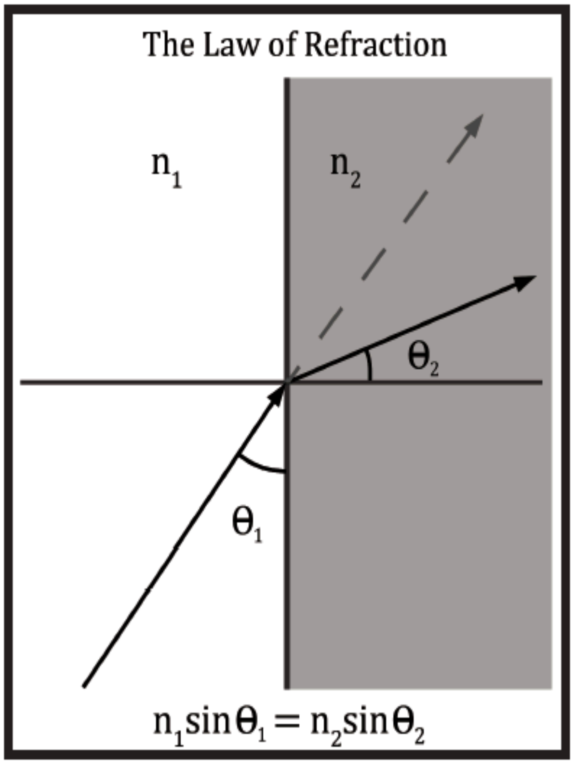
$nD=\sin\theta_1/\sin\theta_2$

Where:

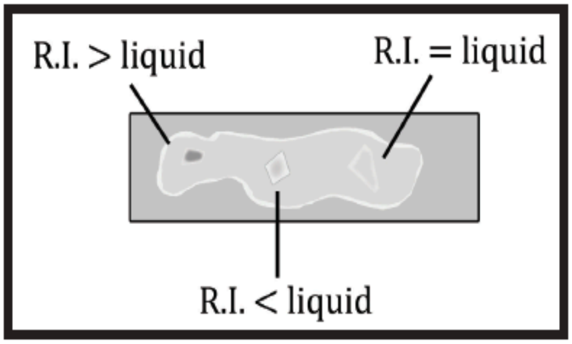
nD =Refractive Index

θ_1=Angle of Incidence

θ_2=Angle of Refraction

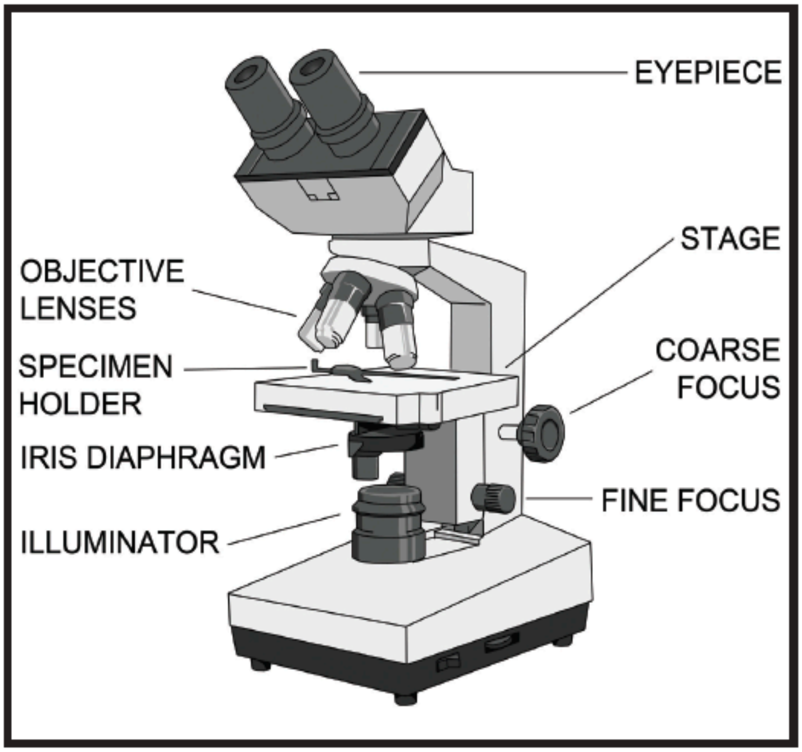


The RI of an unknown piece of glass may be determined in several ways. Manually, the RI may be determined microscopically. In this analysis several drops of a liquid of known RI are placed upon a microscope slide. The glass sample to be analyzed is cleaned and is then placed in the liquid upon the slide. During microscopic analysis the edge of the glass shard will be identifiable by a bright outlining halo. This line is called the Becke line. The distance between the microscope magnifier and the sample changes as the microscopic focus is adjusted. As this distance changes the Becke line can be observed moving into or away from the glass chip being analyzed. If the Becke line moves toward the glass as the distance between the magnifier and the sample increases, then it can be determined that the RI of the broken glass is larger than the known RI of the liquid. Conversely, if the Becke line moves toward the glass as the distance between the magnifier and the sample decreases, then it can be determined that the RI of the glass fragment is less than the known RI of the liquid. Once it is determined that the RI of the unknown glass is either larger or smaller than the known RI of the liquid being used, the glass is removed from the slide, washed, and the analysis is repeated with a different liquid of known RI shifted in the direction of the RI of the glass. For example, if it was originally determined that the RI of the questioned glass was larger than that of the first liquid, a second liquid is selected with a larger RI and the glass is reanalyzed. This process continues through the use of liquids of known RI by decreasing the RI range bracketing the RI of the glass. When the Becke line is observed to disappear, the proper RI has been selected and the RI of the liquid is equal to the RI of the glass.



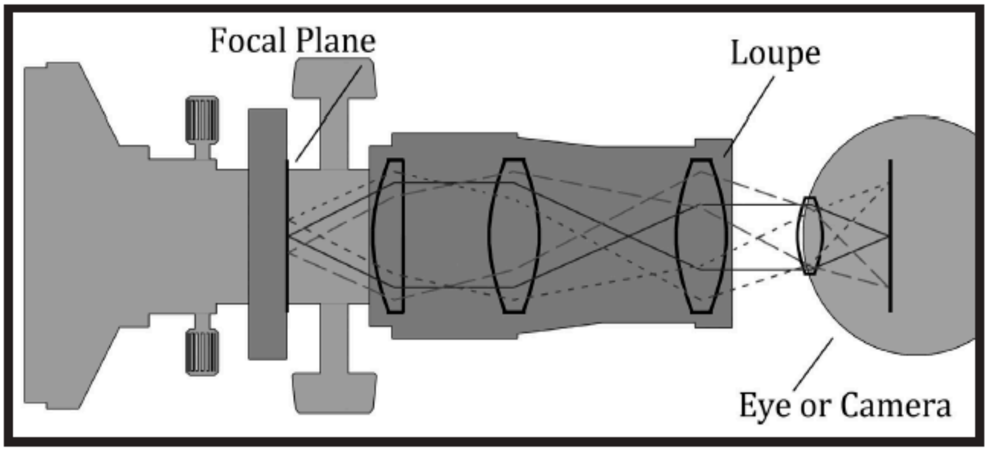
This RI determination may also be automated using a Glass Refractive Index Measurement (GRIM) system. A GRIM system employs a phase-contrast microscope with a temperature-controlled hot stage that allows for precise heating and cooling of the sample being analyzed. This technique also utilizes a microscope slide containing glass fragments, in this case, placed in immersion oil. This slide is then positioned upon the hot stage and the microscope is focused and aligned. As RI is temperature dependent, the temperature of the stage is then adjusted so that the refractive index of the liquid is higher than that of the glass sample. During analysis the contrast between the glass shard and the oil is monitored as the instrument lowers the temperature through the match point (temperature of minimum contrast) of the glass and the match point is recorded. This process is then repeated by raising the temperature up through the match point.

Glass Fragment Identification



These two points are then averaged to give the match point temperature of the sample. From this sample the RI is calculated from calibration data prepared previously with glass standards of known RI. This method of RI determination is more precise than the manual method; however, it is also more costly as it requires an additional piece of equipment within a forensic laboratory.

In addition to comparisons made by RI, forensic glass samples may be identified and compared by their atomic composition, the individual atoms comprising the glass molecules. This may be done in several ways, such as through the use of X-ray Diffraction (XRD) or Laser Ablation-Inductively Coupled Plasma-Mass Spectrometry (LA-ICP-MS). In XRD analysis a glass sample is bombarded with X-rays, and the atomic composition of the glass is determined through detection of the characteristic scattering of those X-rays by the electron clouds of the individual atoms comprising the sample. The scattering pattern is then analyzed by specialized computer software to determine these atoms. In LA-ICP-MS analysis a small portion of the sample is removed from the surface by laser irradiation. This removed sample portion is then converted to atomic ions (charged atomic particles) by inductively coupled plasma, an energy source created by time-varying magnetic fields to produce an ionized (charged) state of matter. An instrument called a mass spectrometer is then used to separate and analyze the characteristic ions produced based upon the mass-to-charge ratio of those ions. This elemental analysis is then compared to the known glass from a crime scene (such as a broken window) or, if no known exists, the type of glass, and in some cases the company that made the glass or even the geographical location where the glass was made, can be determined from the composition.

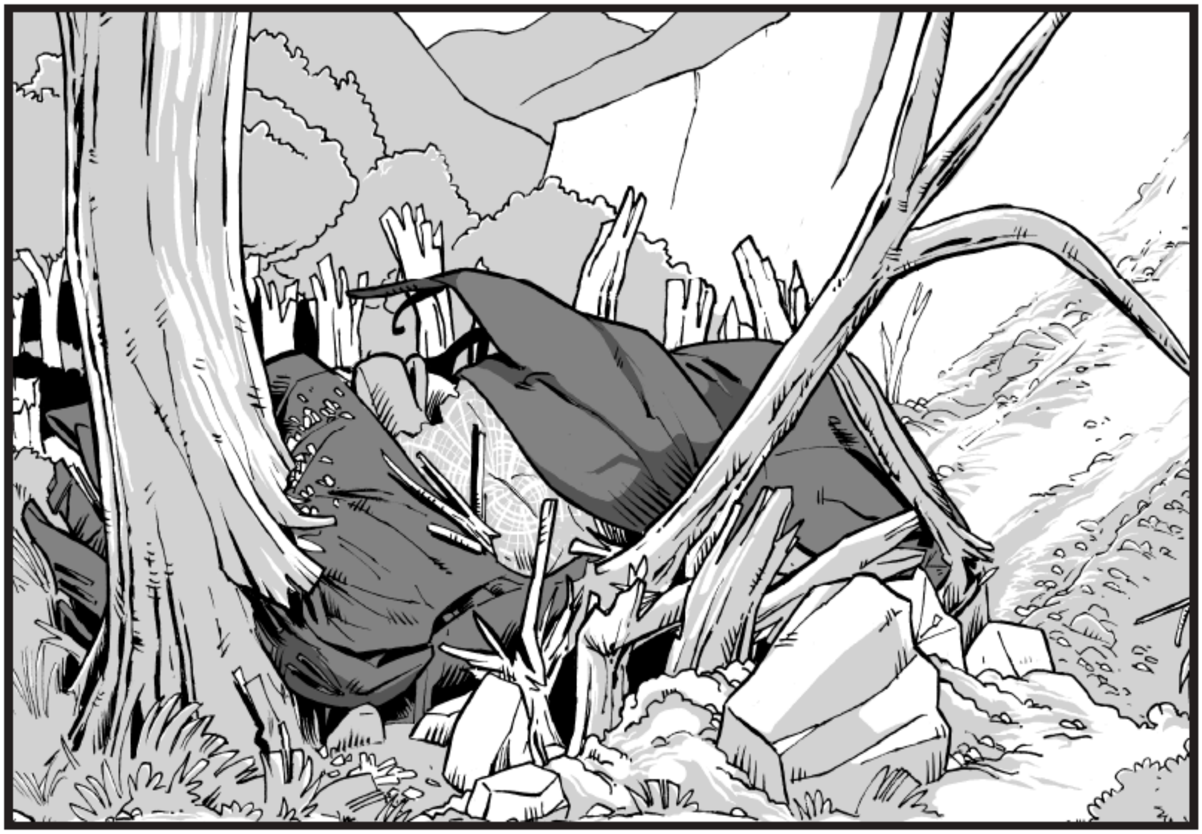


The Investigation

NINE days ago, during the night of a sudden summer thunderstorm, the Mondelo family car went over the side of Backbone Mountain and caught fire on impact. Three bodies were found in the wreckage; an adult woman, a teenage male, and a female child. All were burned beyond recognition. The three victims were identified as Louise Mondelo and her children, Wally and Jan, by personal effects that survived the fire.

Pictures of the scene were recorded but, due to the rainstorm, the crash was initially believed to be simply a tragic accident and was not treated as a crime scene. When Lyle Mondelo could not be reached and was found to be missing, he became a possible suspect, and the wreckage was thoroughly processed. The scene was substantially disturbed and some evidence was undoubtedly lost however, upon retracing the path of the vehicle, investigators found several pieces of broken glass lying in the roadway. Becoming increasingly more suspicious of foul-play, the broken glass fragments were packaged and retained. In addition, investigators cut and removed a section of charred carpet from the vehicle for further laboratory analysis. The bodies, as part of an ongoing criminal investigation, were kept in the county morgue.

The small town of Highland Park was shocked, since nothing this terrible had ever happened in the area. Tips from neighbors and friends poured into the police department, but none of the tips were eyewitness accounts or provided specific information regarding the car accident. Lyle was the likely suspect but was nowhere to be found. An all-points bulletin was issued for everyone to be on the lookout for Lyle Mondelo. He was presumed armed and dangerous and to be driving a missing, blue, 1993 Ford Ranger with Tumbling Water Land Development Co. logos. Four days ago, Lyle Mondelo's credit card was used to purchase gasoline and food at a gas station in Texas.



The Investigation

When contacted, business associate John Wayne Gretzky told investigators that Lyle had been slipping into a deep depression because of trouble at their jointly owned business, Tumbling Water Land Development Company. Gretzky also hinted that there had been problems in the Mondelo family. At this time, investigators noticed that John had a large bite mark on his upper arm. When asked about the wound, Gretzky claimed to have been bit during a bar fight the night before and allowed the bite to be photographed. He was not held or charged with any crime.

Background Investigation

With no additional leads, policed launched a full investigation into the Mondelos. Louise Wilson and Lyle Mondelo had met at college while receiving Business Degrees in Management. They married in college and moved to Highland Park, Louise's hometown, after graduation. The town was still ailing at the time, suffering from the shut down of the mines a little over a decade ago. Although at first Lyle thought their business prospects in the small town were poor, he soon discovered that money could be made developing land for the private lodges and ski resorts that employed most of the residents.

After returning to Highland Park, Louise ran into her old high school sweet heart, John Wayne Gretzky. While talking to him, Louise learned that he was also a developer. Glad to see an old friend, and thinking that a favorable business relationship could develop, Louise asked John to meet with her and Lyle over dinner. Lyle and John soon became friends, and rather than compete for business against each other, the three decided to join together and start Tumbling Water Land Development Company.

A year after Tumbling Water was founded, Louise conceived her first child, Wally. Friends of the Mondelos said that Lyle suspected Louise and John of having an affair at the time, and the two nearly divorced. The couple worked out their relationship with the help of a marriage counselor.

Tumbling Water became prosperous and was able to buy several hundred acres of land adjacent to Blackrock River, a prime recreational waterway. Soon thereafter, Louise had another child, Jan, and took leave from the office to work from home while she raised the two children. Friends say that Louise never really went back to Tumbling Water, even after the children were older and in school. Their friends also suggested that Lyle and Louise's relationship was healthier with them not working together.

Tumbling Waters' lawyer told investigators that she began preparing bankruptcy papers for the company about a year ago; the ski resort was dragging out negotiations for a property purchase, and the company's other business deals weren't making enough profit to keep the business afloat. Soon after being asked to begin the bankruptcy filing, though, she said an unexpected deal was made to build a number of fishing cabins on the Blackrock River land. That was enough to keep the business going, and after that, Tumbling Water began making deals at a steady rate.

A potentially related case recently touched on the Mondelos' lives. Three weeks ago, a crystal methamphetamine lab was discovered in an abandoned camper on Tumbling Water land. Louise's nephew, Mitch Wilson, and John Wayne's brother, Larry Gretzky, were found in the lab and indicted for possession with intent to sell the 6 kilograms of meth found in the lab. Two days later they were both released on bond, posted by Lyle Mondelo and John Gretzky. Mitch and Larry gave no names of possible suppliers or dealers.

Two weeks before the crash, Louise Mondelo filed for divorce. Friends say she told them that she suspected Lyle of being involved with drugs, but that the friends believed she was involved with John Wayne Gretzky again. Two days later after filing for divorce, Louise requested a restraining order against Lyle, stating that Lyle had harassed her and the children. Louise also told police that she was afraid that Lyle might try to take the children away.

When attempting to contact Mitch Wilson and Lar ry Gretzky for questioning about the car accident, police discovered that they had both skipped town along with Larry's girlfriend, Mary Bradey. Authorities believed that their disappearance could be related to the accident, and they were described as possibly armed and dangerous in the warrant posted for their arrest.

Two days ago, an abandoned blue Ford Ranger with out-of-state plates was found on a strip of New Mexico highway. The pickup was dirty and a headlight was broken, but investigators noticed a Tumbling Water Land Development Co. sign on the back tailgate. Forced entry was apparent. Upon access to the truck, investigators discovered several pieces of trace evidence and sent it to Highland Park for analysis.

At the Scene

This morning the bodies of two deceased victims were discovered in a remote fishing cabin on property owned by Tumbling Water Land Development Company. The cabin, isolated from view of the main road and deeply buried in the thick woods, lies along the bank of the Blackrock River and is accessible only by a gravel road cutting into the forest. Soon after the bodies were discovered, the small cabin was surrounded by police tape and investigators combing the scene in search of evidence.

Detective Murray, the lead investigator in the case, explained, "A Girl Scout on a hiking trip found the victims about an hour and a half ago. There are two bodies inside, both in advanced stages of decomp; PMI undetermined. The female vic was identified as Louise Mondelo, the same woman identified in the car that ran off Backbone Mountain and caught fire during the storm last weekend. The bodies are in bad shape, but hopefully we'll get a positive ID when DNA analysis comes back."

Inside the cabin the smell of advanced human decay was overwhelming. The overturned chairs and tables led investigators to conclude that a violent struggle had taken place. The smaller body, dressed in a blouse and jeans, was found near the phone in the kitchen. The larger corpse was dressed in a man's polo shirt and slacks lying in the corner to the left of the door, and blood covered the walls and floor around him. Investigators collected maggots from the corpses to help establish a time of death and collected DNA samples from both victims. While processing the scene, flesh was discovered scraped across the stone of the fireplace, and blood and skin were found on a piece of firewood lying near the woman's body. Samples of both were collected for analysis. The wounds upon the head of the female victim appeared consistent with the firewood, but a definitive determination was difficult to make due to the state of decay. Outside of the cabin, a set of tire tracks were found deeply rutted in the mud and grass. As none of the investigators had driven near that area, dental stone molds were cast of the tracks and pictures were taken to preserve evidence.

The Evidence

As crime scene investigators begin to suspect foul play in the deaths resulting from the vehicle crash along Backbone Mountain, they retraced the path of the vehicle and stumbled upon several pieces of broken glass lying together in the roadway above the crash site. These glass fragments were collected and retained for further analysis.

When the abandoned Tumbling Water Land Development Co. truck was found along the highway in New Mexico, the local authorities were contacted. As investigators inspected the truck they noticed that one of the front headlights was broken. Remembering the broken glass near the Backbone Mountain crime scene, they collected a sample of glass from the broken headlight and sent it to the forensic trace evidence laboratory for analysis.

All glass samples were pre-ground with a mortar and pestle in prepararation for analysis.

Persons of Interest

The Mondelos

Louise Ann Mondelo, the 38 year old wife of Lyle Mondelo and mother of Wally and Jan, is also one of the owners of Tumbling Water Land Development Company. Friends say that Louise was in an unhappy marriage and had recently filed for divorce.

Lyle Christopher Mondelo, the 40 year old husband of Louise Mondelo and father of Wally and Jan, is a part owner of Tumbling Water Land Development Company along with his wife.

John Wayne Gretzky

John Wayne Gretzky is 41 years old. He is a friend and business partner of the Mondelo's in the Tumbling Water Land Development Company. According to rumors, John Wayne and Louise had a brief affair when Lyle and Louise first moved to Highland Park. He is known around town to be a greedy businessman, and has been suspected of shady deals in the past.

An unknown woman of similar height and build has been identified as Louise Mondelo. Although her identity is uncertain, this other woman was found either driving the Mondelo family car with two children preliminarily identified as Wally and Jan, or in a remote fishing cabin with a man who has been preliminarily identified as Louise's husband Lyle Mondelo.

Pre-Lab Questions

1. What is trace evidence?

2. What information can trace evidence provide?

3. What is commonly the first step in glass analysis?

4. How is refractive index calculated?

5. If the refractive index of a medium is known to be 1.50, and the angle of incidence is 46.8°, what is the angle of refraction?

6. When placed in liquid of a different refractive index, what is the bright outlining halo surrounding a glass fragment called?

7. What are two ways the atomic composition of a glass fragment may be determined?

Lab Procedure

Lab 1: Microscopic Determination of Refractive Indices of Known Samples

1. Prior to analyzing evidence collected from the crime scene and abandoned truck you will practice the techniques required to perform a microscopic refractive index determination using some non-evidentiary known samples of glass. Glass edges may be sharp so great care must be taken when handling fragments. Do not handle glass fragments without wearing proper personal protective equipment, including gloves and goggles.
2. Select a reference glass sample, carefully open the sample container, and remove several glass fragments.
3. Prepare a microscope slide by placing one to two pieces of glass onto the slide. (Note: Smaller fragments are more easily analyzed than larger fragments)
4. Place 1-2 drops of Liquid 1 (Refractive Index=1.45) onto the glass fragment ensuring that the liquid surrounds the edges of the fragment; cover with a coverslip.
5. Place the slide onto the microscope stage; at the lowest power of magnification, focus the microscope on the glass fragment.
6. Once the glass fragment has been properly focused, switch the microscope to the next highest magnification objective and refocus the microscope. (Note: Closing the microscope diaphragm will likely aid in glass fragment visualization)
7. Repeat this procedure until the objective, when focused, allows the glass fragment on the slide to fill the majority of the field of view while still allowing all edges of the fragment to be viewed.
8. Adjust the microscope diaphragm and light intensity until the Becke line, the halo of light at the edge of the glass fragment, is easily visible.
9. Once the microscope has been properly focused, carefully adjust the focus noting the direction of movement of the Becke line as the objective lens moves toward and away from the sample.
10. If the Becke line is observed moving toward the glass as the distance increases, the refractive index of the sample is larger than the known refractive index of the liquid. If the Becke line is observed moving toward the glass as the distance decreases, then it can be determined that the RI of the glass fragment is less than the known RI of the liquid.
11. Record your observations on the Data Collection page, and repeat steps 2-11 with additional fragments of the same known glass sample and Liquid 2 and Liquid 3.
12. Based upon your analysis, record the experimentally determined refractive index on the Data Collection Page. Repeat steps 2-13 with the other reference glass sample.

Lab 2: Processing the Evidence

13. Carefully open your sample of questioned glass obtained from the crash site on Backbone Mountain.
14. Analyze the glass sample in the same manner as described for the known samples in Lab 1.
15. Once your analysis of this sample is complete and your observations and the experimentally determined refractive index have been recorded, return the evidence to the container and close the lid.
16. Repeat steps 1-3 for the known glass sample taken from the headlight of the abandoned truck.
17. Once evidence analysis is complete, as a group, determine whether the evidentiary sample of glass collected from the roadway is consistent with that of the glass taken from the broken headlight of the abandoned truck. Discuss your theories as to why or why not.

Data Collection and Calculations

Lab 1: Microscopic Determination of Refractive Indices of Reference Samples

Bottle Glass (Soda-Lime Glass)

Liquid Used	*Observations*	*As Distance Increases, Becke Line Moves (Circle)*	*Approximate Refractive Index*
Refractive Index Liquid 1 (n=1.45)		*Toward Glass* *Toward Liquid*	
Refractive Index Liquid 2 (n=1.47)		*Toward Glass* *Toward Liquid*	
Refractive Index Liquid 3 (n=1.49)		*Toward Glass* *Toward Liquid*	

Vehicle Headlight Glass (Borosilicate Glass)

Liquid Used	*Observations*	*As Distance Increases, Becke Line Moves (Circle)*	*Approximate Refractive Index*
Refractive Index Liquid 1 (n=1.45)		*Toward Glass* *Toward Liquid*	
Refractive Index Liquid 2 (n=1.47)		*Toward Glass* *Toward Liquid*	
Refractive Index Liquid 3 (n=1.49)		*Toward Glass* *Toward Liquid*	

Data Collection and Calculations

Lab 2: Processing the Evidence

Questioned Glass Sample-Collected from Backbone Mountain Near Vehicle Crash Site

Liquid Used	*Observations*	*As Distance Increases, Becke Line Moves (Circle)*	*Approximate Refractive Index*
Refractive Index Liquid 1 (n=1.45)		*Toward Glass* *Toward Liquid*	
Refractive Index Liquid 2 (n=1.47)		*Toward Glass* *Toward Liquid*	
Refractive Index Liquid 3 (n=1.49)		*Toward Glass* *Toward Liquid*	

Comparison Glass Sample-Collected From Abandoned Truck in New Mexico

Liquid Used	*Observations*	*As Distance Increases, Becke Line Moves (Circle)*	*Approximate Refractive Index*
Refractive Index Liquid 1 (n=1.45)		*Toward Glass* *Toward Liquid*	
Refractive Index Liquid 2 (n=1.47)		*Toward Glass* *Toward Liquid*	
Refractive Index Liquid 3 (n=1.49)		*Toward Glass* *Toward Liquid*	

Post-Lab Questions

1. Based upon your experimentally determined refractive indices of both the bottle glass and headlight glass, which medium would change the path of light traveling through it the most?

2. Did your group determine the glass collected from the site near the vehicle crash to be consistent with the glass collected from the truck's broken headlight? Explain your reasoning.

3. Based upon your examination of the evidence presented, can it be concluded that the abandoned truck's broken headlight produced the broken glass on the road near the Backbone Mountain crash site?

4. Based upon your knowledge of the crime(s) and your examination of the evidence presented, what is your hypothesis about the events surrounding the deposition of the broken glass?

5. If further comparison of the glasses was desired, what techniques could be utilized?